CTRI to Scope Calibration

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Abstract

This document explains the procedure used to measure the delay, inserted between the kicker extraction pulse and the first sample of the BCTFI.400344 acquisition for both CTRI firmwares Apr/2008 ($30.6ns \pm 1ns$) and Dec/2010 ($26.6ns \pm 1ns$).

1 History of changes

26/09/2011 First upload to the OHR.
27/09/2011 Title changed. Sign of delay in abstract corrected. Added interpretation of the sign respect to the CTRI timestamps.

2 Introduction

The CTRI is a general purpose synchronization module generally used as a counter that can be clocked either by an external clock or an internal GPS aligned 40MHz. The counting can also be started either via an internal trigger or via an external start. The core design has been made with VHDL and implemented in an Spartan3 FPGA.

The reference CTRI in HCA442 receives the kicker extraction pulse on its External Start and generates a 'zero delay' pulse if there is a valid CNGS cycle on output 3. The delay from External Start to Output #3 is unknown. Additionally the acquisition is triggered by the CTRI Output #3. The delay inserted by the scope is also unknown.

As there is more than one clock domain that can generate a pulse on a given output it has been impossible to assign an IO flip flop per output. Therefore every VHDL implementation, and every counter configuration requires a separate calibration if an accuracy at the level of the 1ns is required. This delay is referred as δ_4 in the BCTFI.400344 to GPS calibration chain. See Figure 1

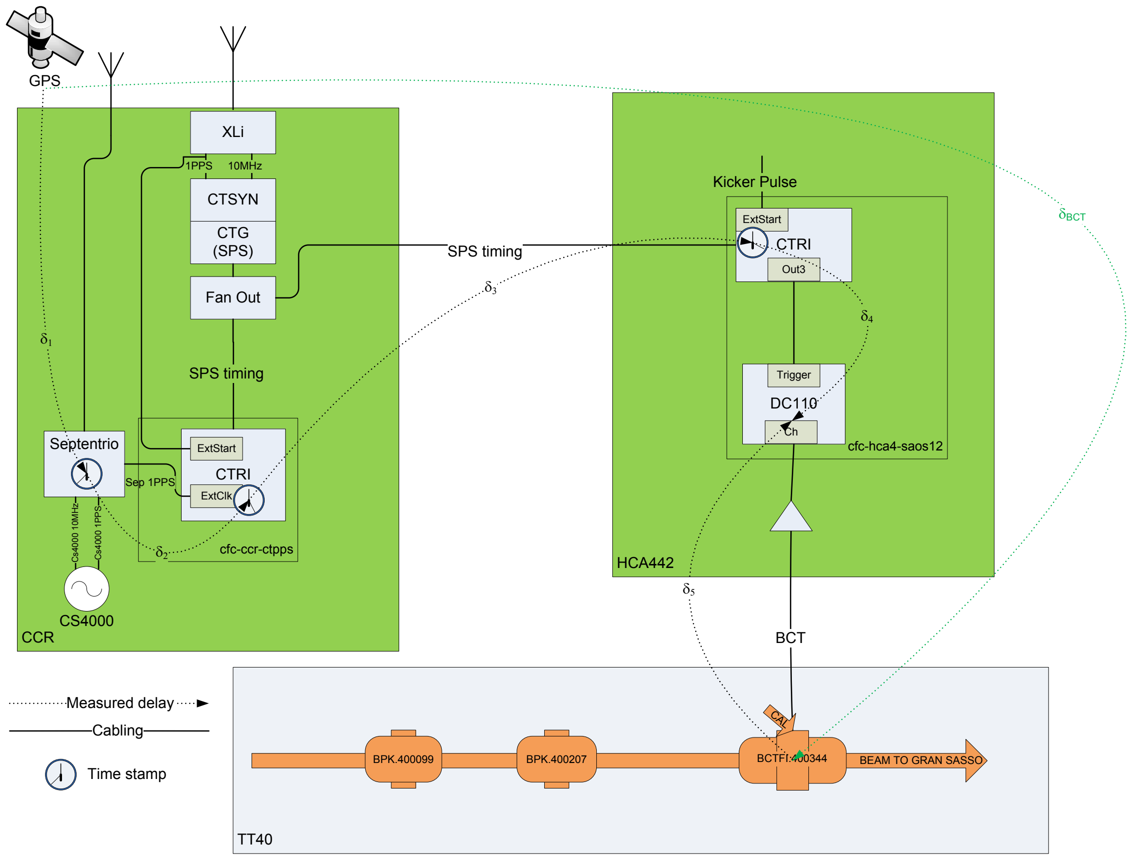

Figure 1: CNGS timing calibration chain.

3 Procedure

Figures 3 and 2 show the two configuration needed to calibrate External Start to waveform delay. In Figure 3 the scope channel is connected to the CTRI's External Start. The scope trigger is cabled as in the CNGS installation. Notice that the trigger is delayed respect to the rising edge of the External Start pulse, precluding the use of the scope in left trigger mode. If the scope trigger is set in center mode, the External Start will be visible on the left of the trigger. This implies that it is necessary to check if both left and centered mode have the same insertion delay.

In Figure 2 both the trigger and the scope channel are cabled with the same signal. In Figure 3 the scope channel is connected to the CTRI's External Start. Both External Start and the scope channel have traveled with the same delay. The scope trigger is cabled as in the CNGS installation. During operation the scope is triggered on the left. Figure 2 shows the calibration setup used to test the skew between trigger and waveform in center trigger and left trigger modes.

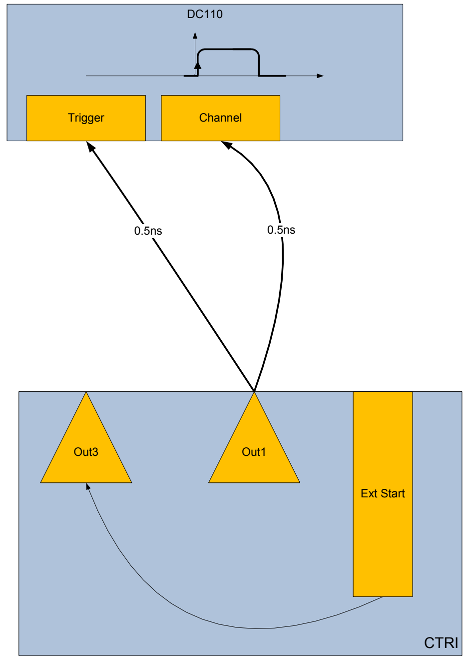

Figure 2: Scope channel input to scope trigger skew. This setup is used to verify that the delays are preserved for trigger center and trigger left mode.

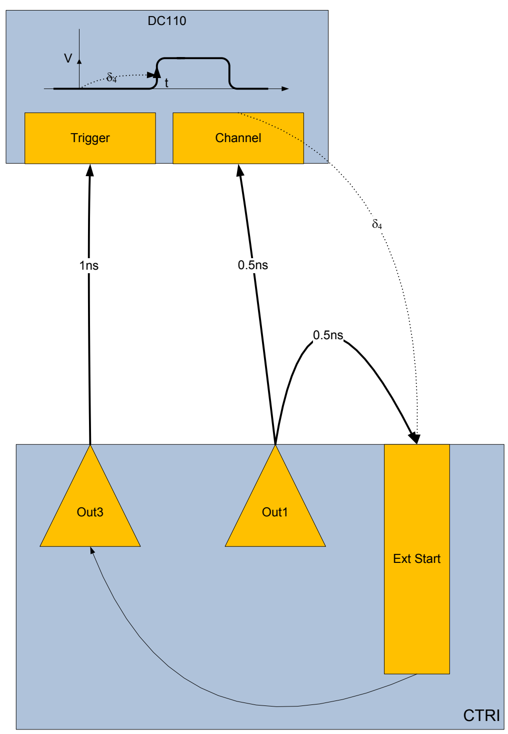

Figure 3: External Start to scope channel delay.

4 Sign Interpretation

The CTRI introduces a delay δ_4 between the external start input and the Scope trigger. This delay must be positive and added to the CTRI timestamps, as the trigger on the scope will always happen after the external start has arrived.

5 Scope Skew in Center and Left Mode Trigger

With the scope configured as in Figure 2 and triggered in center and left mode we deduce that both have approximately the same skew ($1.9ns$):

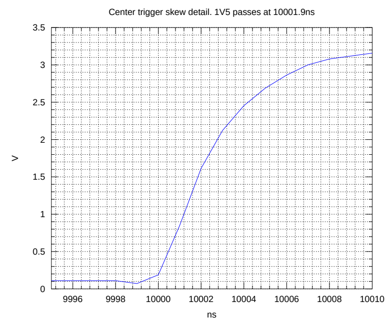

Figure 4: Same trigger and channel input. Trigger mode center. 20000 samples at 1GS/s. Signal averaged.

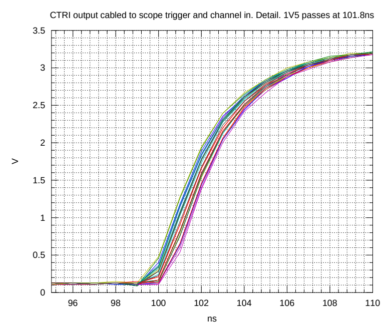

Figure 5: Same trigger and channel input. Trigger mode center. 200 samples at 1GS/s. Signal averaged.

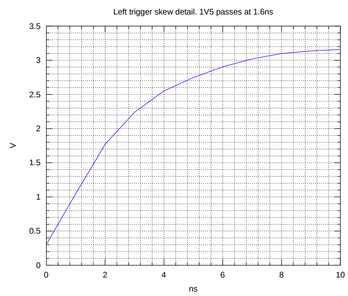

Figure 6: Same trigger and channel input. Trigger mode left. 20000 samples at 1GS/s. Signal averaged.

6 Calibration of Apr/2008 Firmware

With the setting as in Figure 3, 20000 samples per acquisition and center mode trigger we obtain the following overlapped waveforms:

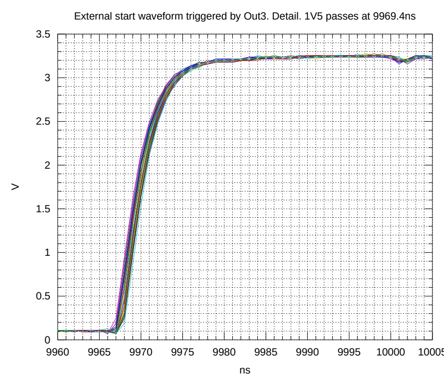

Figure 7: CTRI Out #3 drives the trigger and Out #1 to the External Start and the Scope Channel Input through a 0.5ns cable. Trigger mode centered. 20000 samples at 1GS/s.

We obtain that the CTRI External Start to the DC110 acquisition delay at a 1.5V threshold is:

$$\delta_4 = 30.6ns \pm 1ns$$

The 1ns rms error is an stimation of possible mismathes in cable lengths, trigger levels and scope stability.

7 Calibration of Apr/2010 Firmware

With the setting as in Figure 3, 2000 samples per acquisition and center mode trigger we obtain the following overlapped waveforms:

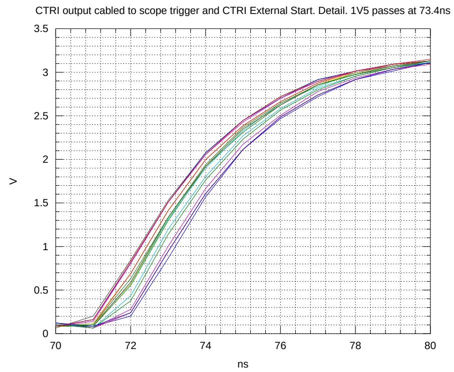

Figure 8: CTRI Out #3 drives the trigger and Out #1 to the External Start and the Scope Channel Input through a 1ns cable. Trigger mode centered. 200 samples at 1GS/s.

We obtain that the CTRI External Start to the DC110 acquisition delay at a 1.5V threshold is:

$$\delta_4 = 26.6ns \pm 1ns$$

The 1ns rms error is an stimation of possible mismathes in cable lengths, trigger levels and scope stability.